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Power from Waste - Convert Waste Heat into Power

Thomas Soulas
Director Business Development,
Advanced Energy Systems

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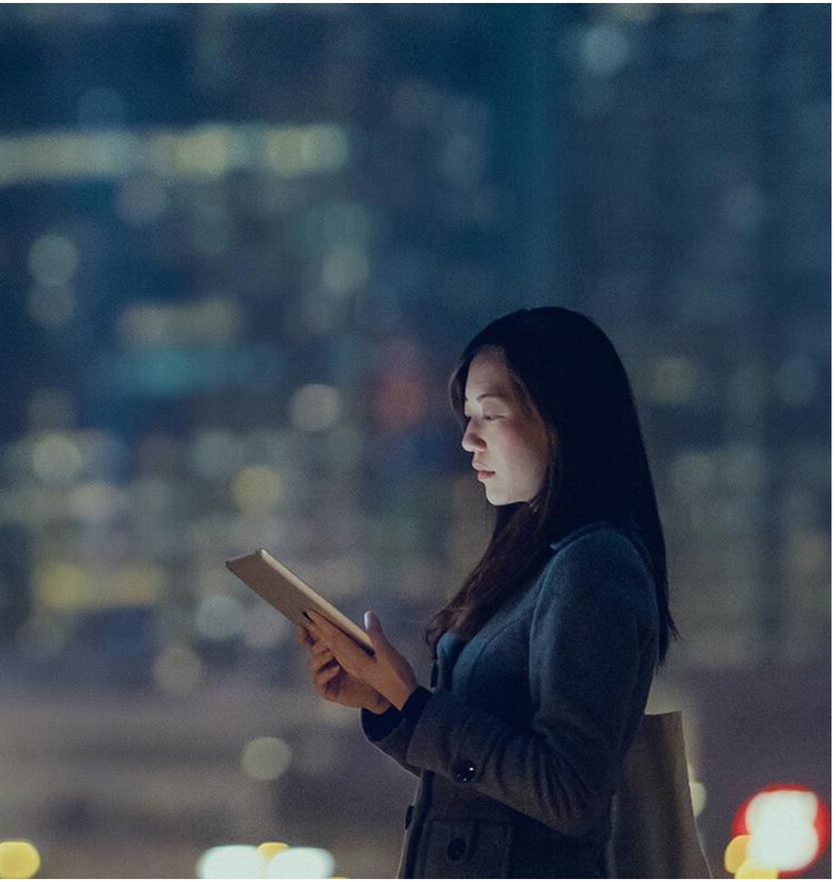

Introduction to Waste Heat to Power

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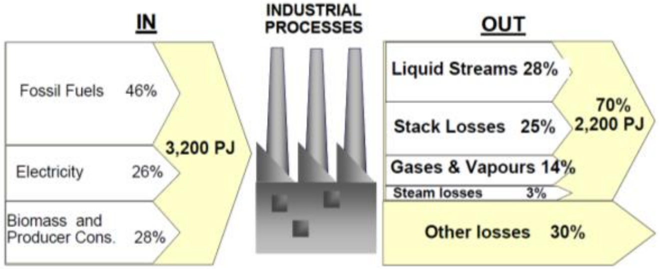
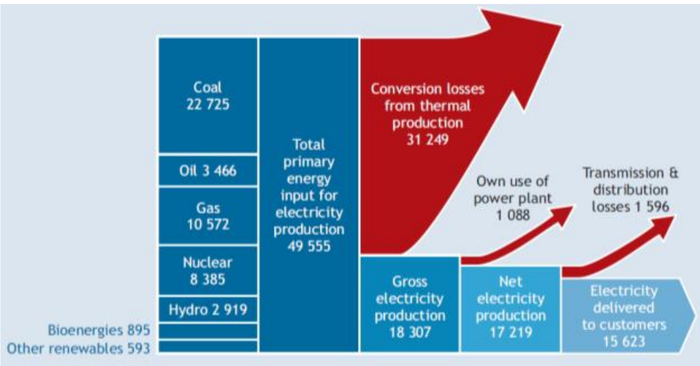
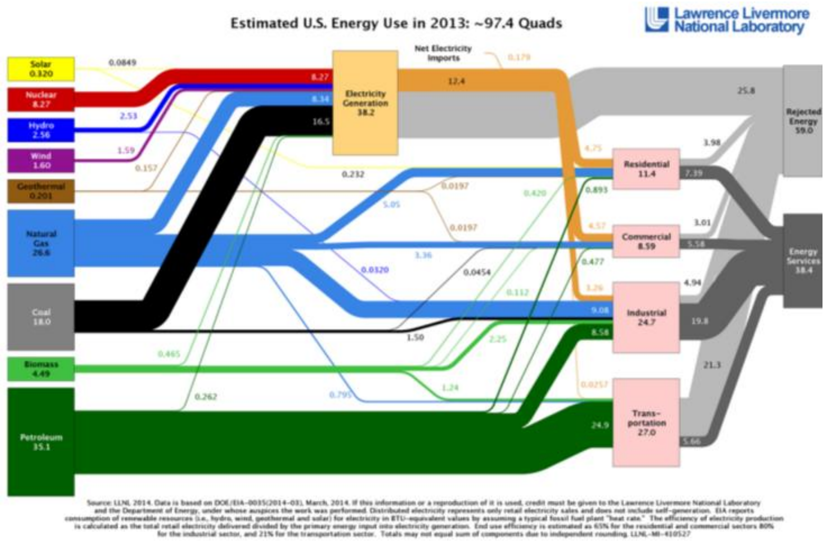


Canada, rejected heat corresponds to 70% of net input



Energy Flows in the Global Electricity System, ~65% of total energy input is lost



US Energy in 2013: ~60% rejected/wasted

Waste/lost heat can be converted into useful energy

Rejected and unused Energy continues to be a REALITY

What is Supercritical CO_2 Waste Heat to Power?

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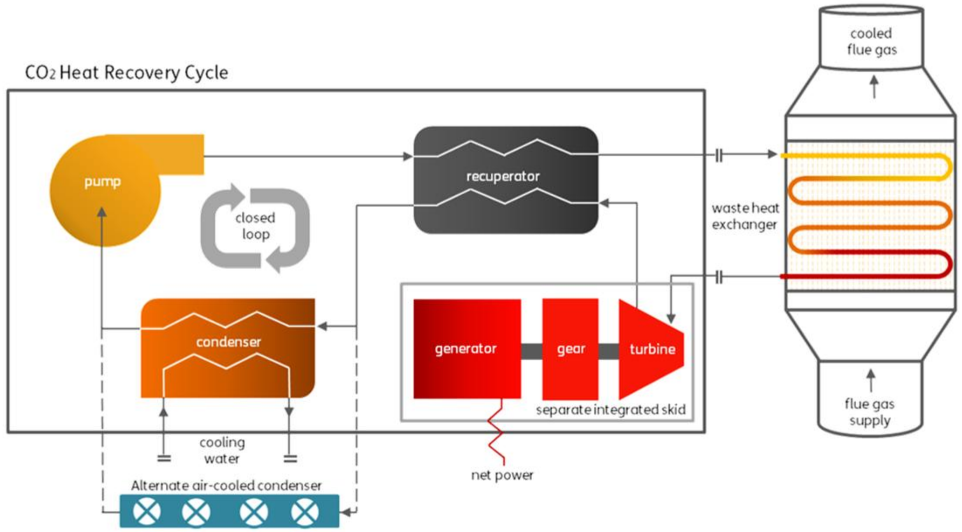
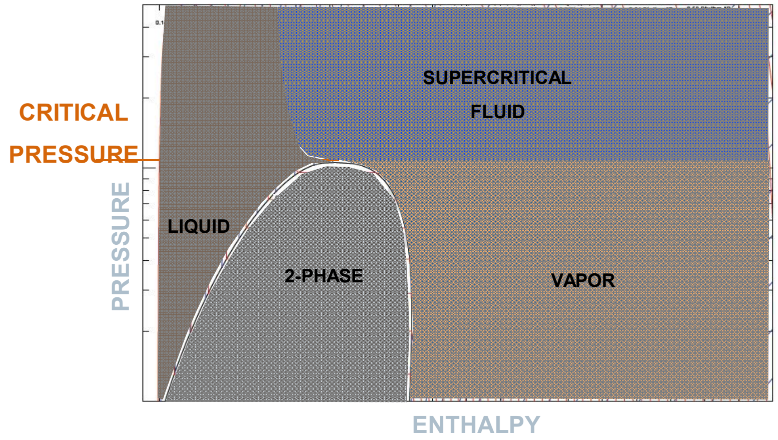
Supercritical CO_2 (sCO_2) Waste Heat to Power Technology Solution

http://www.dresser-rand.com/products-solutions/systems-solutions/waste-heat-recovery-system/





Dresser-Rand (DR) & Echogen – Strategic Partnership

DRESSER-RAND.

Dresser-Rand Invests in Echogen Power Systems' Innovative Waste Heat Recovery Technology

Expands Environmental Solutions Platform and Extends Market Opportunity for Dresser-Rand's Product Portfolio

HOUSTON, Feb. 24, 2011 /PRNewswire/ -- Dresser-Rand Group Inc. ("Dresser-Rand") (NYSE: DRC) announced today that Dresser-Rand Company has entered into a definitive agreement with Echogen Power Systems of Akron, Ohio under which Dresser-Rand will acquire a minority interest in Echogen as well as certain license and exclusive market rights to Echogen's technologies and intellectual property. Dresser-Rand's investment will be used to advance Echogen's technology development, including the design and construction of waste heat recovery systems utilizing turbo-expanders provided by Dresser-Rand.

Value Proposition

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Water-Free Option	• Totally dry, water-free, closed-loop process • Air cooled condenser (water cooled condenser optional)
Compact	• No exhaust bypass stack required • 25-40% smaller footprint than steam; minimally invasive retrofit
Flexible	• Suitable for remote operation; no boiler operator required • 20-30 minutes to full load
Efficient	• Simple heat transfer, no boiling process (supercritical) • Direct in-stack WHX, no intermediate fluid required
Competitive	• Lower LCOE (Levelized Cost of Electricity) • Competitive OPEX and long term services contracts
Clean	• Produces electricity without incremental emissions • Working fluid is stable, benign and non-flammable

Value Proposition - Footprint

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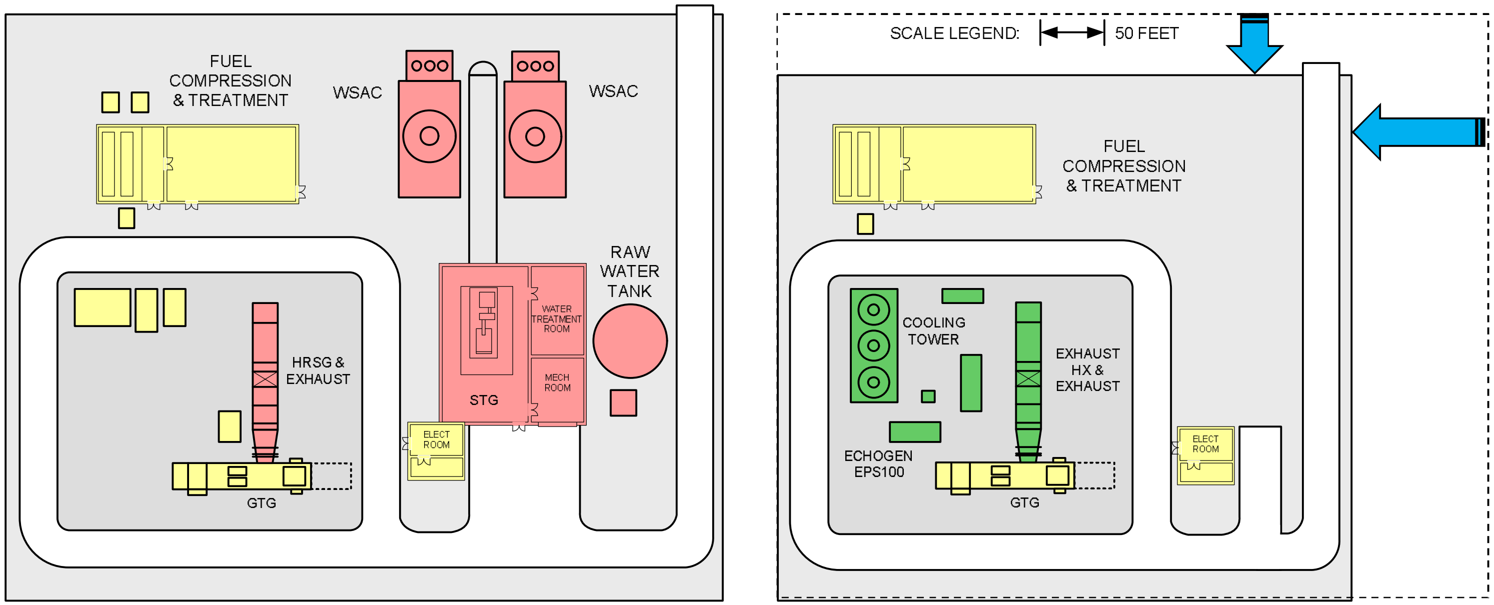

Gas Turbine / Generator **HRSG** **sCO_2 Heat Engine**

5 ½ Acre Site **4 Acre Site**

25% reduction

The EPS100 – Commercialization of Pilot Unit

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Designed for 20-35 MW Gas Turbines (GTs)

- Siemens SGT-600, SGT-700, SGT-750
- Siemens SGT-A30 RB & SGT-A35 RB [Industrial RB211]
- GE LM2500 / Solar Titan 250 / Combination of smaller GTs
- 8.0 MW gross / 7.3 MW net (ISO)
- Work conducted on further cycle efficiency enhancements toward 9.5 MW gross

Physical Configuration (see EPS100 flyer)

- Process skid (right) + Power skid (above)
- Control house + CO_2 storage tank and transfer system
- Cooling system (air or water) + Waste heat exchanger

Accomplished: Factory qualification testing
Final step: Field deployment & operation
Commercially available

EPS100 – Factory Qualification Testing

Adobe Acrobat Document

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1 Completed all Phases I-IV of testing

- I: Validation of components
- II: Full speed no load
- III: Durability
- IV: Partial load endurance test

2 System control & stability fully demonstrated

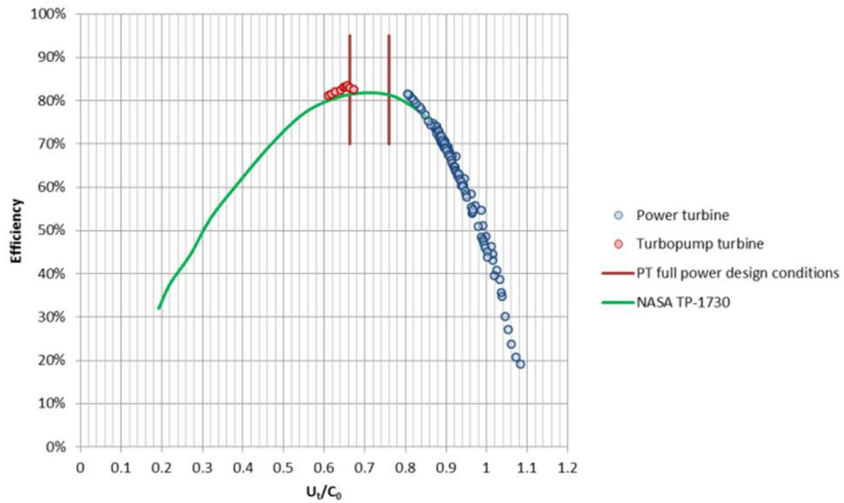
3 Component performances meet or exceed expectations

4 Turbopump run to max conditions

5 Generator speed control stability demonstrated

6 Power turbine electrical output = 3.1 MWe max to date (limited by available heat on test stand)

7 Run time: 310 hours turbopump / 150 hours power turbine



EPS100 Pilot Project – Compression Station in North America

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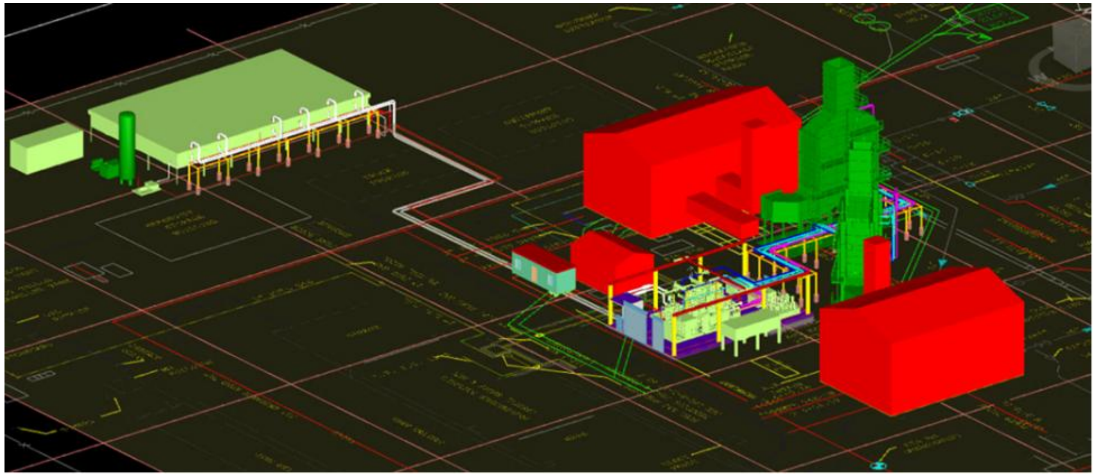
- Opportunity installation for gas turbine exhausts
- Remote operation
  - Control and isolation of GT exhaust stream
  - No impact on station operation
- Compact arrangement
- Skid-mounted equipment with minimal installation
- Air-cooled condensers
- Option for bypass stack & diverter valve



- **Dresser-Rand offering:**
  - **Turnkey solution**
  - **Service contracts**
- **Power sold to the grid by host**
- **Option of project developer**
- **FEED under way (commissioning targeted early 2020)**

Application in LNG – Value Proposition of EPS100

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Gastech
Conference & Exhibition
Korea | KINTEX 1 | 24 – 27 March 2014

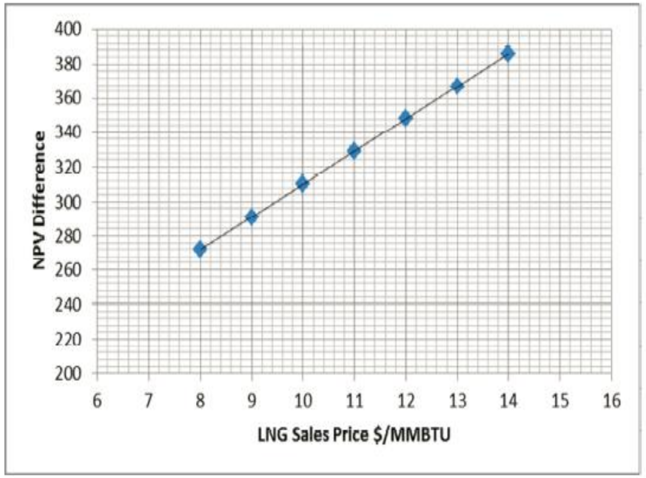
C. B. Meher-Homji, D. Messersmith, P. Pillai
Bechtel Corporation

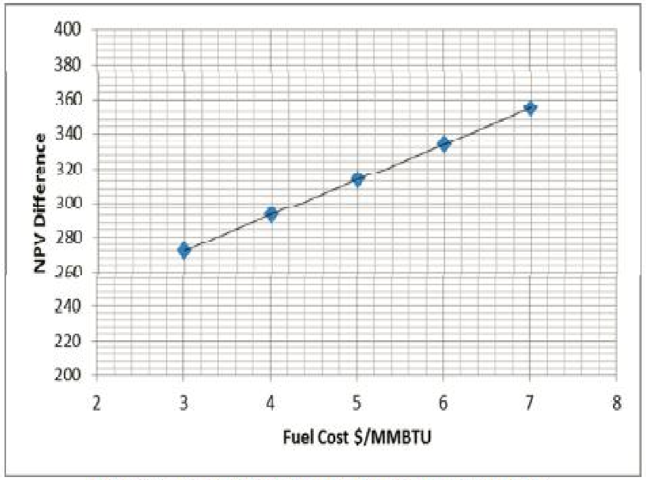
A NPV type analysis was conducted of the two scenarios-

- Case 1- Traditional power generation
- Case 2- Power generation using sCO_2

The following assumptions were used:

- Life 20 years
- Discount Rate 10%
- LNG Cost FOB 8$/MMBTU
- Fuel Cost 3$/MMBTU
- Plant Availability 95%
- CO_2 Emission Tax $40/tonne





Acknowledgements: We gratefully acknowledge the assistance of Dresser-Rand and Echogen Power Systems.

Future Applications Offshore

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Waste heat recovery for offshore applications

5. A CO_2 cycle was preferred to Organic Rankine cycle (ORC) as an alternative to the standard steam cycle. The main reason for not investigating the ORC option in detail are working fluid stability issues, GWP and/or flammability and toxicity of the fluids, preliminary calculations that showed better compactness of the CO_2 cycle, and other on-going projects focusing on ORC. Hydrocarbons was however considered for a lower temperature power cycle utilizing heat from compressed gas.

8. EFFORT shows that steam and CO_2 bottoming cycles offshore are of similar weight and footprint
   a. CO_2 systems have slightly smaller footprint but potentially larger weight due to the high pressure system requiring lager wall thickness of piping, making piping weight 3 times higher for CO_2 than for steam.
   b. A compact waste heat recovery unit using super-critical CO_2 can be designed with 40% less weight than a unit using steam in a sub-critical once through steam generator.
   c. If distances from the WHRU to the remaining system is long, the weight advantage of a compact CO_2 unit may be offset

EFFORT Consortium in Norway

Tell Us About Your Waste Heat

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If you would like more information about how your application can benefit from the Dresser-Rand / Echogen Technology, please complete the "Tell Us About Your Project" form

Potential waste heat source(s) at the facility:

Waste Heat Source	Source 1	Source 2	Source 3
Source Description (if gas turbine exhaust, exact model)			
How is heat currently removed (vented, stack, cooling tower, etc.)?			
Temperature (indicate unit)			
Throughput; Flow rate (indicated unit)			
Exhaust gas composition (list or attach)			
Minimum allowable reduced temperature (indicate unit) (e.g., temperature of waste heat leaving our exchanger, if available)			
Maximum allowable pressure drop in the stack/system, if available			
Existing power demand in kW or MW			
Preferred voltage output from Echogen system (e.g. 480 volt, 3 phase, 60 hertz)			
Average ambient air temperature (indicate unit)			
Ambient air temperature range throughout the year, if available (indicate unit)			
Heat sink preference: ➢ Air cooling? ➢ Water cooling? If so, average temperature of cooling water as already available (indicate unit)? ➢ No preference			
Current or anticipated cost of power @ plant			
Are operational data available (Y/N)			
Are site layout drawings available (Y/N)			

Tell Us About your Project

Thank you!

Thomas Soulas
Director Business Development,
Advanced Energy Systems
PG DR

Houston, Texas, USA

Mobile: +1 713 598 4425

E-mail: thomas.soulas@siemens.com

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